Assessment of
Solar Energy Systems

Assessment of Solar Energy Within a Community:

Summary of Three Community-Level Studies

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This summary report is part of the "Technology Assessments of Solar Energy Systems (TASE)" project supported by the U.S. Department of Energy, Technology Assessments Division/Office of Technology Impacts, Assistant Secretary for Environment. The objective of the TASE project is to provide policymakers an analysis of the potential health, environmental, and social/economic consequences of large-scale (national in scope) commercialization of solar technologies. This report is a summary of three studies concentrating on the potential community-level impacts of such commercialization. The results of these studies provide enrichment of the national-level TASE project by identifying for policymakers specific community-level issues that may arise as a result of federal policy. The three studies are:

1. Community-Level Environmental Impacts of Decentralized Solar Technologies

2. Community Impediments to Implementation of Solar Energy

3. Three Solar Urban Futures: Characterizations of a Future Community under Three Energy Supply Scenarios.

Throughout the document scenarios and views of social/economic and institutional futures are presented. These should be viewed as illustrations for exploring impacts of policy implementation strategies, not as projections of a likely future.

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The Office of the Assistant Secretary for Environment of the Department of Energy through its Division of Technology Assessments initiated in mid-FY 1978 a comprehensive project relating to the extensive use of solar energy technologies. The project, entitled "Technology Assessment of Solar Energy Systems" (TASE), will determine the long-range environmental and socioeconomic impacts of solar energy systems.

The primary objective of the TASE project is to determine the range of potential consequences to the environment and to public health and safety resulting from widespread implementation of major solar resource technologies in accordance with the national goal set by the President for the year 2000. The results of the project are intended to assist DOE policymakers in determining the optimum course for solar energy deployment considering public benefits and environmental and socioeconomic impacts.

The overall focus of the TASE project is to provide impact analysis of various solar technologies at the national, regional and subregional levels. To perform these computations, the Strategic Environmental Assessment Simulation (SEAS) model will be utilized to compare environmental residuals and economic factors resulting from the Domestic Policy Review (DPR) solar base case scenario (year 2000) to the DPR maximum practical scenario (year 2000) and to a base year (1975). Since impacts at the local or community level are inaccessible through a SEAS computation, a series of community-level studies were initiated. Furthermore, since the community level impacts (e.g., land use, institutional requirements, etc.) may be greater than state, regional or national impacts with regard to decentralized technologies, these studies are an important continuation to the national level impact assessment.

The community level studies are divided into three task areas: (1) community impact analysis, (2) threshold impact analysis and (3) solar city end-state analysis. The overall purpose of the studies is to investigate

Decentralized Solar Technologies." The threshold impact analysis condu
by a team from SRI, International (formerly Stanford Research Institute
was issued as a report, "Community Impediments to Implementation of Sol
Energy." The end-state analysis was undertaken by the Urban Innovation
Group of the University of California, Los Angeles. Its final report w
entitled "Three Solar Urban Futures."

The objective of this report is to describe the basic assumptions
methods and findings of each community-level study. The report is orga
into the following sections: conclusions, study assumptions and defini
community-level scenario development and a summary of each task area.
cause each of the community studies appears elsewhere as a separate rep
this document is intended to provide a summary of the major findings an
the relationship of these results to the Phase II activities of the TAS
program.

Several general conclusions emerge from the individual community-level studies. Even though each task area used a different study methodology and format, the results provide some generalized trends that should enrich the overall TASE analysis. The conclusions are related to the scenario and study assumptions and should be viewed as illustrations of potential opportunities and impacts and not as projections of a likely urban future.

Land Use Impacts

The first general conclusion is that a community can meet the on-site energy demands assumed by the scenario in all but the most dense land-use sectors (e.g., central business district). In the residential sector, however, this may require removal of 15 to 35 percent of the tree canopy. Further, it may be required that greater than 80 percent of the total area in the industrial sector and about 50 percent of the available commercial parking area be covered with solar collectors.

Community Expansion

Secondly, decentralized solar technologies can produce substantially greater amounts of on-site energy supply than was prescribed by the scenario Greater solar development can be realized by using "shared neighborhood systems" and by employing passive design in all new buildings. As evidence in the hypothetical "solar city" (Future 3), a community may become energy self-sufficient if 650 acres of photovoltaic arrrays are added in the commer cial sector and 2800 acres of on-site collectors are augmented to the industrial sector.

Institutional Impacts

tions, and the aesthetic concerns of the public and planning agencies. In order to meet the levels of on-site solar collection that are described in this study, these impediments must be removed.

Building and Urban Design

A fourth general conclusion is that passively designed buildings in futur residential, commercial and industrial sectors need not look different from existing versions that consume up to 25 times more energy. However, the overa appearance of a community with a high level of solar development (e.g., large collector areas, tree removal, etc.), may be quite different based on current urban design and aesthetic criteria.

Community-Level Planning

Finally, there are great opportunities for implementing decentralized sola technologies within a community. The implementation, however, will require the integration of urban and energy planning at the local level in order to av potential aesthetic, institutional and land use impacts.

III. STUDY ASSUMPTIONS AND DEFINITIONS

To place the analyses of the community-level studies in the proper context, it is necessary to clearly delineate the basic assumptions made by the three task areas. Understanding the assumptions made by the working groups allows proper evaluation of the study results and conclusions. In Table 1, the basic study assumptions are briefly outlined; a discussion of each assumption in more detail follows.

Coordination of Community-Level Studies to the TASE Project: Assumptions 1-4

The importance of the first four assumptions lies in defining the relationship of the community-level studies to the work being done by the other laboratories for the national technology assessment of solar energy (TASE) project. The use of the Department of Energy national energy scenarios will ensure consistency and allow for more reasonable comparisons of the results of the community-level studies with the rest of the TASE efforts. In this respect, assumption 4 concerning the solar technologies and their application and characterizations is particularly important; it delineates the very definition of what constitutes "solar." The purpose of these assumptions was to ensure at the outset of the community-level studies that the utility of work would be increased by the coordination with TASE.

Decentralized Solar Technologies: Assumptions 5-7

The distinctive and innovative nature of the community-level studies is expressed in assumptions 5-7. The majority of research in the past has emphasized centralized technologies of the conventional types as well as the

1) Coordinate efforts with the national technology assessment of solar energy (TASE).

2) Use DOE national energy scenarios as a framework for the studies.

3) Adapt national energy scenarios to form a community-level scenario.

4) Use solar technologies, applications and technology characterizations from TASE Phase I.

5) Emphasize decentralized solar technologies.

6) Emphasize analysis of impacts from various solar scenarios rather than emphasizing implementation methods and feasibility.

7) Assume the solar systems are cost competitive with those they replace.

8) Assume no radical changes in lifestyles and institutions.

9) Assume present trends in city form (urban morphology) will continue.

10) Assume the national average land use mix for the prototype communities.

These assumptions are important and demonstrate that the results of the community-level studies address important problems that exist but have not yet been analyzed.

Special Assumptions 8-10

The remaining three assumptions (8-10) are working assumptions which deal with the practical approach of the three task groups. Assumptions 8 and 9 ensure that the basic continuation of the status quo is considered. Although some drastic or radical changes may be expected to occur, for example, if the price of oil would increase sharply over a short period of time or if some other "energy crisis" were to occur, it is still important to consider the impediments to solar that exist in present society. The resistance to change should not be underestimated. By assuming no radical changes in lifestyle will necessarily happen, the working groups can gain insight into a realistic and probable future. Assumption 10 again provided the tasks with a common starting point which will aid the intercomparison of the results of the three task groups.

In addition to the basic study assumptions, several terms are used in the community-level studies with specific meanings. "Decentralized solar technologies" have been defined to include those technologies which can be implemented within community boundaries and are not part of the utility grid

The following technologies were considered:

- solar heating and cooling (space heating, hot water and air conditioning for residential and commercial buildings)
- photovoltaics (electricity for residential, commercial and industrial buildings)
- wind energy conversion (electricity)
- industrial and agricultural process heat (from biomass and solar thermal conversion)

available August 1978, could not be precisely allocated to the community level. DPR scenarios describe only the national energy supply and are not directly comparable to the energy flows in a single community. In addition, the community-level studies could not use an a priori characterization of the absolute amount of energy flowing through a community or sub-community element as this was to be, in a large part, a product of the land use pattern architectural design, and institutional actions defined in the individual tasks. Rather these studies needed as a starting point a description of the mix of energy resources used to supply a community.

In order to tie the community level studies as closely as possible to the TASE program, the energy information used by the studies was based on the available DPR scenarios and the TASE technology characterizations. Further, it became clear that the identification of institutional and land-use impacts would be enhanced by the use of a high level of decentralized solar technologies. It was therefore decided to use the interim DPR scenario which allowed the greatest relative contribution of solar technologies as the basic model for the community energy supply mix. The version of the DPR scenarios available in August/September 1978, which met this goal was the thirty-two dollars per barrel "maximum solar" scenario.

The solar energy supply for each sector (residential, commercial and industrial) was disaggregated into specific TASE technologies by information provided by the DPR staff and available TASE analyses. The resulting picture of sector-by-sector energy supply was converted from the amount of energy contributed by each technology into percent contribution of each technology to the sector's energy needs. This information was grouped into centralized (e.g., central grid) and decentralized technologies. Only the decentralized technologies were listed by their individual contribution. Central technologies were listed collectively as the amount of energy entering a community

technologies. Certainly no one community will use all of these possible supply options.

3) The intent of the scenario is not to constrain the design options and impact investigations of each project. Rather the scenario provides a guide for the general level of decentralized solar energy which should be included in the design of each community and its component parts.

4) Technologies sited outside the community (e.g., most biomass and wind systems) are de-emphasized since they will not directly impact the community.

5) The transportation sector has been excluded since the DPR scenarios did not provide for solar energy in that sector.

Category	Total %
1. Space heating/cooling, hot water (non-electric)	
a. On-Site Solar	
• solar thermal	23.04
• passive design	6.14
• biomass (wood)	3.52
b. Other	
• oil	2.27
• gas	10.60
• synthetic fuel	0.74
SUBTOTAL	46.31
2. Electric	
a. On-Site Solar	
• wind	1.15
• solar thermal	0.22
• photovoltaics	2.42
b. Utility Grid	
• space heating/cooling, hot water	29.87
• other electric	20.03
SUBTOTAL	53.69
TOTAL	100.0

Approximate percent of residential energy provided

	%
1. Space heating/cooling, hot water (non-electric)	
a. On-Site Solar	
• solar thermal	10.74
• passive design	2.15
• biomass	0.45
b. Other	
• oil	4.35
• gas	20.61
• synthetic fuel	0.41
SUBTOTAL	38.71
2. Electric	
a. On-Site Solar	
• wind	1.61
• solar thermal	0.50
• photovoltaics	3.37
b. Other	
• space heating/cooling, hot water	33.37
• other electric	22.44
SUBTOTAL	61.29
TOTAL	100.0
Approximate percent of residential energy provided by decentralized solar energy technologies	18.8

	%
1. Process Heat	
a. On-Site Solar	
• solar thermal	12.42
• biomass	9.23
• synthetic fuel	0.0
b. Other	
• oil	2.13
• gas	13.84
• coal	6.75
• synthetic fuel	1.12
• central electric	1.42
SUBTOTAL	46.91
2. Other Energy Requirements	
a. On-Site Solar	
• wind electric	0.26
• solar thermal electric	0.40
• photovoltaics	0.25
• synthetic fuel	1.03
b. Other	
• oil	2.13
• gas	13.13
• coal	13.13
• synthetic fuel	2.00
• central electric	20.75
SUBTOTAL	53.08

V. COMMUNITY IMPACT ANALYSIS

The objective of this study is to examine the physical, spatial and land-use-related impacts of decentralized solar technologies applied at the community level by the year 2000. The results of the study are intended to provide a basis for evaluating the way in which a shift toward reliance on decentralized energy technologies may eventually alter community form. This project has been conducted in parallel with two related efforts: a study of end-state community design and an analysis of institutional impediments to widespread solar technology implementation.

The project assumes that in many physical respects, communities in the year 2000 will resemble parts of cities as they exist today and that the level and types of solar technologies identified by the "maximum solar" scenario of the DPR will be used. For the purposes of this study, a land-use impact is related to competition for space and, more specfically, to insufficient collector area on site to achieve a particular level of solar penetration.

Land-Use Types

Six land-use types representative of those found in most U.S. cities are analyzed according to solar penetration levels identified in the DPR "maximum solar" scenario for the year 2000. The scenario is translated into shares of end-use demand in the residential, commercial and industrial sectors. These proportions become the scenario goals to be met by the use of decentralized solar energy systems. The percentage of total solar energy demand is assumed to be 36.5 percent, 18.8 percent and 23.5 percent in the residential, commercial and industrial sectors respectively. The community-level scenario stipulated that a certain percentage of the total demand be

sensitive land-use patterns. Patterns studied are single-family detached dwellings and multiple-family row house apartments in the residential sector; strip commercial development, warehousing and central business district in the commercial sector; and central-city facilities in the industrial sector. These land-use types vary with respect to end-use demand and density characteristics which influence on-site solar supply. Table 5 identifies th energy demand and density for the land-use types considered in this study.

Solar Supply Systems

Six different solar energy supply systems ranging from thermal collectors with current output and short-term storage (i.e., two to three days) to cogenerating photovoltaic arrays with long-term storage (i.e., between seasons) are examined. Each of these technologies has a theoretical potential to meet any given mix of end-use demands based on its output of thermal and electrical energy. Table 6 lists the theoretical potential of the selected technology systems. Characteristics of the technology that determine its potential are the storage capacity, quality of energy produced and system efficiency. These factors define the proportion of demand for each land-use type that can be met if the required amount of collector area is available.

Methodology

The method for analysis consists of determining the maximum on-site collector area for each land-use type in the residential, commercial and industrial sectors. This determination includes an evaluation of passive (south wall) design potential and measurements of the available unshaded col lector area from aerial photographs. The evaluation of solar potential of each individual parcel is augmented with an estimation of several alternativ

The results of the study are the following:

- Assuming a typical land-use mix of the land-use types studied, a community can achieve the DPR "maximum solar" goals for the year 2000 using on-site technologies with current performance. Table 7 contains the percent of total energy demand for each land-use type that can be provided by the direct solar technologies.
- Of the individual land-use types, only the commercial central business district cannot achieve the scenario goal on-site. The deficit in the central business district, however, can be more than offset by the ability of other land-use types to achieve a greater level of solar development.
- In the residential sector, low density detached single-family development (i.e., urban sprawl) is not required in order to meet the solar scenario.
- Detached single-family development can achieve greater independence from conventional energy sources than denser residential patterns only by using cogenerating photovoltaic systems with long-term storage.
- Central-city industrial locations would require use of other renewable sources (e.g., cogeneration, wood or municipal residues) in addition to direct solar technologies to meet the solar scenario.
- Decentralized solar technologies can produce substantially greater amounts of on-site energy supply than the DPR scenario projects. The increased levels are limited by the quality and availability of energy supplied by a given technology and by the demand for that particular quality of energy within each land-use sector (see Table 8).

storage facility;

-- transfer surplus thermal and electrical energy to land-use types deficient in on-site solar potential; and

-- control land development patterns through land-use regulations to eliminate environmental characteristics that constrain on-site collection.

- Environmental characteristics of a community which reduce available collector area include:

  -- vegetation

  -- street orientation

  -- lot configuration

  -- density

  -- roof configuration

  -- adjacent buildings

Table 9 shows the environmental characteristics which act as limiting actors in the case study areas.

- Environmental characteristics of a community which acted as limiting factors can be eliminated by use of shared energy supply systems and long-term storage.
- Environmental characteristics of the community limit on-site collectors primarily in the higher density land-use types (i.e., multiple family residential and central business district).
- Demand for water to meet thermal storage requirements although an impact with ~~each~~ technology is insignificant relative to total water consumption within the community.
- Potentially significant secondary impacts may occur from the disposal of hazardous wastes associated with the working fluids.
- Visual intrusion of solar collectors will be more significant in the central business district, central-city industrial locations, and in high density residential areas than in low density

duce significant physical impacts using even direct thermal technologies with current performance. All but the most dense commercial development (i.e., central business district) can achieve the solar scenario goal without a transfer of surplus thermal and electrical energy from other land-use types. In addition, these technologies can replace substantially greater amounts of on-site energy demand when communities follow various courses of action.

The results of this analysis illustrate that there are identifiable environmental characteristics that individually or collectively limit the community's ability to meet end-use demand. In cases where these characteristics limit on-site collection, their influence decreases when a large number of individual installations are combined into a district system. Implementation of district systems, however, will introduce a new set of considerations involving the integration of future energy planning goals into the broader social and institutional setting.

Sector[1]	Density Of Case Study Areas[2,3]	Energy Demand/Gross Acre
Residential: SFD Single Family Detached Dwellings	8 d.u./acre	$.03 \times 10^{10}$ BTU
Residential: MFD Row House Apartments (multiple family)	31 d.u./acre	$.79 \times 10^{10}$ BTU
Commercial: STRIP Strip commercial development	F.A.R. = 2.3	$.13 \times 10^{10}$ BTU
Commercial: WH Warehousing	F.A.R. = 4.6	$.11 \times 10^{10}$ BTU
Commercial: CBD Central business district	F.A.R. = 6.7	1.00×10^{10} BTU

Industrial:

In the industrial sector, central city facilities identified as adaptable to solar energy use by Battelle and ITC (1977) were selected for case study.

NOTES:

1 These land-use types occur in all large metropolitan areas and comprise most of the residential and commercial land area. The single case study examples of the energy-sensitive land-use types were drawn from three cities in the United States: Denver, Baltimore, and Minneapolis.

2 d.u. = dwelling unit

POTENTIAL OF SIX TECHNOLOGY SYSTEMS TO MEET ENERGY END USE DEMANDS

Technology	Short-term storage	Long-term storage
Thermal collectors with performance comparable to currently available	1. 70% heat 80% hot water 70% cooling[1]	4. 100% heat 100% hot water 100% cooling[1]
Thermal collectors with a 33 percent increase in efficiency and using planar reflectors to increase output 50 percent (50 percent reduction in collector area)	2. 70% heat 80% hot water 70% cooling[1]	5. 100% heat 100% hot water 100% cooling[1]
Cogenerating photovoltaics with 80 percent the output of current photovoltaics and 80 percent the output of current thermal collectors	3. 70% heat 80% hot water 100% cooling 100% power	6. 100% heat 100% hot water 100% cooling 100% power

NOTES:

1. Use of solar thermal air conditioning is assumed only for the commercial sector.

CHNOLOGY ith Rooftop Collectors)	LAND USE TYPES				
	Residential		Commercial		
	SFD	MFD	STRIP	CBD	WH
1. Thermal Collectors w/Existing Output	36.5[3]	33.0[5]	32.0	3.6	56.0
2. Thermal Collectors w/Improved Output	36.5[4]	44.0[5]	43.0	7.2	56.0
3. Cogenerating Photo-voltaics	59.6[5]	62.0[5]	35.0	6.2	78.0
4. Thermal Collectors w/Existing Output	55.1	46.0[5]	27.0	3.3	65.0
5. Thermal Collectors w/Improved Output	55.1	66.0[5]	48.0	6.7	79.0
6. Cogenerating Photo-voltaics	79.5[5]	61.0	57.0	9.1	93.0
Scenario Goal[1]	36.5		18.8		
n-Site Solar Collection Goal[2]	31.9		16.8		

NOTES:

1. Scenario goal for all solar technologies.

2. Photovoltaic and thermal collectors; also assumes some passive design.

3. Assumes removal of up to 35 percent of the tree canopy.

Percent of Total Energy Demand Met by Each Solar Technology Assuming Unlimited Collector Area

TECHNOLOGY (with Unlimited Collector Area)	LAND USE TYPES				
	Residential		Commercial		
	SFD	MFD	STRIP	CBD	WH
1. Thermal Collectors w/Existing Output	40	44[3]	43	39[4]	56
2. Thermal Collectors w/Improved Output	40	44	43	39[4]	56
3. Cogenerating Photo-voltaics	85	86[3]	86	86[4]	87
4. Thermal Collectors w/Existing Output	55	66[3]	61	56[4]	79
5. Thermal Collectors w/Improved Output	55	66	61	56[4]	79
6. Cogenerating Photo-voltaics	99	99[3]	49	99[4]	99
Scenario Goal[1]	36.5		18.8		
On-Site Solar Collection Goal[2]	31.9		16.8		

NOTES:

	Energy Supply System Characteristics					
	Individual/ Short-Term Storage			Shared/ Long-Term Storage		
NATURAL[3]	Passive So. Wall	Roof	Roof[2] + Site	(Parcels) Block	Study Area	Beyond Study Area
Latitude						
Climate						
Topography						
Obstruction of solar access by vegetation	SFD Strip CBD	SFD	SFD			
BUILT						
Street pattern: Orientation	SFD WH CBD	CBD	CBD	CBD	CBD	
Street pattern: Lot configuration	SFD MFD					
Density: Available collector area relative to required collector area	SFD CBD	MFD CBD	MFD Strip CBD	CBD	CBD	
Density: Building location relative to lot lines	SFD		MFD			
Roof configuration: Area and orientation		SFD				
Obstruction of solar access by buildings	SFD,MFD Strip CBD	MFD CBD	MFD CBD	CBD	CBD	

SFD: Single Family Dwelling (detached)

THRESHOLD IMPACT ANALYSIS*

Introduction

The main objective of the analysis is to examine the ability of commu and their institutions to progressively absorb changes incurred by adaptin an energy system consisting primarily of dispersed solar technologies. Sp fically, the goal is to identify likely institutional community-level impe ments to the widespread implementation of solar technologies by the year 2 and particularly to focus on those impediments causing projected delays of years of more in deploying any of the solar technologies.

Methodology

The methodology adopted for the study consists of:

(1) The preparation of a national-level background description of the seven institutional sectors judged most pertinent to solar technology implementation: utilities, finance, community planning, construction, environmental protection, special consumer groups, and legal and insurance interests.

(2) The formulation of a hypothetical city (prototypical city) of 100,000 population, in which a prorated national average of the DPPRC maximum solar technology scenario for the year 2000 is depicted. Solar technology implementation in the prototypical city includes projected sizes and configurations for each type of technology and approximate magnitudes of the residential, commercial, and industrial solar panel coverages to meet the assigned shares of heat and electrical loads for the city (see Table 10).

(3) The conduct of two one-day workshops with representatives from the seven institutional sectors, each of whom had knowledge of and

to obtain further inputs from geographically dispersed institutional representatives.

Results Presented as Time Delays

The results of the study are presented in two formats. In the first, th findings are organized by the time frames of delays in solar implementation caused by the inherent difficulties a national energy policy would encounter i changing the way a given institution responds to specific solar technologies. Delay categories of 10 years or more, 6 to 8 years, and 3 to 5 years were selected; all were assigned under the assumption that a strong national policy promoting adoption of solar technologies would be in effect.

An assumption is also made that no major U.S. crisis occurs and that institutions will behave in their customary modes of doing business. The associations with time frames represent best judgments from the analysis of the past, present, and projected future practices of the institutions involve and implies the delays that should be expected after effective national-level policies have been implemented.

The following three insitutional impediments are categorized as the most intractable since delays in achieving acceptance of the solar technologies at a level considered in this study can be expected to be 10 or more years:

- Time delays are perceived in the acceptance and adoption of solar technologies by the residential and commercial building industries. The amorphous nature of the building industry, consisting of numerous relatively independent entities, the lack of vertical integration of the entities, and the personal contact method of doing business all result in time delays of adoption of new technologies and practices.
- Widespread solar technology adoption within a community is

judged to be more amenable to policy influence than the previous set. Accordingly, the following have been assigned to the 6 to 8 year impediment category:

- In the near term, financing is a major deterrent to solar implementation, which can be eliminated if national policy firmly supports solar technology. The desired stimulus can take one or both of two thrusts: stimulate market demand for solar with various monetary incentives to the user--rapid depreciation, tax credits, subsidies, and so on--or take a more direct approach by providing government loan guarantees.
- If the solar technologies are to be implemented to the maximum solar scenario of the year 2000, utilities will have to be directly involved in installing, maintaining and controlling residential solar systems. This involvement, which will likely stimulate public resistance, is potentially a major barrier.
- Cooperative/neighborhood-scale installation offer an excellent opportunity to overcome or avoid many of the economic barriers to on-site energy generation and storage. There is little precedent, however, for existing institutional structures to permit or encourage such options to be exercised. Even in new construction arrangements for metering individual use, maintenance and interaction with utilties and local building codes make shared installations extremely difficult to implement.

The 3 to 5 year category contains 11 identified impediments. Their assignment to this category was not meant to diminish their potential magnitude or importance; rather, it reflects that they are judged to be readily amenable to change through national energy policy. If these issues are not resolved, however, many of the 3-to-5-year impediments could emerge as longer term barriers to widespread solar technology implementation. The 3-to-5-year impediments

water heating are currently the only solar technologies generally installed around the country, and these still represent a very small fraction of the total potential market. Although both the general public and institutions usually support the adoption of these technologies, the implementation rate necessary to reach the goal for the year 2000--on the order of a million ne installations and, additionally, a million retrofits a year--are very unlik to occur wihtout a strong federal policy to speed the process. An underlyi concern with all of the solar technologies is the extent to which utilities will be willing and permitted to participate in the installation, maintenan and control of the equipment.

Other solar technologies--particularly those of a larger scale, such a wind energy conversion, biomass conversion, photovoltaics, and solar therma --have their own peculiar sets of problems resulting in institutional imped ments and implementation delays. These problems include financing, siting, environmental hazards, legal and regulatory issues, and gaining the coopera tion of planning agencies and local utilities.

Summary

In summary, the study has assembled the complete array of institutiona problems expected to emerge when solar technologies are implemented on a national scale. Since this first phase of the TASE study was designed to d with solar implementation from a national perspective rather than attemptin a regional specification, which is the goal of Phase II, the identified impediments will apply to different degrees in various areas of the country The study has attempted to identify and provide a basic understanding of th institutions that are most likely to be involved with solar installations, provide some understanding of the complex ways in which they must interrela to achieve a widespread implementation by the year 2000, and by so doing, t

PROTOTYPICAL CITY SOLAR TECHNOLOGY SUMMARY

	Residential	Commercial	Industrial	Total City
rea	4,000 acres	490 acres	590 acres	11,150 acres*
otal solar panel coverage	43% of residences equipped for 70% efficiency	274 acres	466 acres	740 acres + residential
equired Solar Technology Units**				
ind Energy Conversion System	95 (100-kW)	47 (200-kW)	5 (1-MW)	147
olar thermal electric	10 (100-kW)	16 (100-kW)	4 (1-MW) (or 2 1-MW)	30
hotovoltaic	101 (100-kW)	101 (100-kW)	2 (1-MW)	204
otal Installations				
	206	164	11	381

This total includes the 5,110 acres devoted to infrastructure and open space.

Figures in parentheses indicate generating capacity per unit.

Introduction

The goal of the end-state analysis is to examine the structure of a typical community as it would appear in the year 2025 under varying solar growth assumptions. Transition problems to the year 2025 were explicitly excluded from this study.

A hypothetical city of 100,000 people is assumed to undergo changes with time coincident with the absorption of solar energy technologies into its community structure. A city is analyzed in its end-state after a period of growth based on three different energy scenarios. Future 1 specifies tha approximately 6 percent of the city's demand is met by solar technologies. It is based on a "business-as-usual" scenario which continues present supply patterns. This scenario depends heavily on fossil fuels imported into the city. Future 2 is based on an extrapolation of the DPR "maximum solar" scenario for the year 2000 in which about 25 percent of the city's energy supply is supplied by solar technologies. This scenario depends heavily on importe electricity. Future 3 represents a hypothetical city that is build de novo to maximize the use of solar energy collected on-site. These three versions of the hypothetical city are identical in terms of demographics (population and land uses), goods and services produced and energy demand. Their differences are compared in terms of physical layout, environmental quality, socioeconomics, and quality of life.

Methodology

A hypothetical city was designed to reflect the median characteristics of existing U.S. cities. In each case, the city consists of prototypical building types in its residential, commercial (including institutional), and industrial sectors. The terms of the study exclude transportation energy from consideration. In the residential sector, four different building type

office building, a small strip commercial building, and a one-story shopping center. Three versions of each prototypical residential and commercial building type are considered: an uninsulated version of a kind common before 1979; a standard version satisfying the ASHRAE 90-75 Energy Standards; and a passive version designed for better solar energy performance. End-use demand is computed for each building prototype. The prototypes are then aggregated for each version of the hypothetical city in proportions calculated to match the given energy supply scenarios and assumed demographic constraints.

Industrial sector energy demand is dominated not by building design characteristics, but by requirements for production and process energy of various qualities. The proportion of this demand that can be met by the given solar technologies is calculated to meet the given energy supply scenarios for each version of the hypothetical city.

Results

The results of the study include the following:

- In Future 1 and 2, the hypothetical city's residential sector can easily meet the on-site energy collection requirements of the given supply scenario. The total residential roof area required for on-site collection is 3.3 percent in Future 1 and 20.2 percent in Future 2 (see Table 11).
- In Future 3, the residential sector can be totally energy self-sufficient (i.e., collecting all needed energy on-site) if there is 80.7 percent coverage of the available residential roof area.
- In Future 1 and 2 the commercial sector can easily meet the on-site solar energy collection requirements. The total available area in the commercial sector covered with collectors

tional 650 acres of land.

- The industrial sector in Future 1 and 2 can meet on-site solar scenario goals. In order to meet the scenario requirements 12.3 percent of the industrial land area in Future 1 and 83.7 percent in Future 2 are covered by solar collectors (see Table 13
- In Future 3, the industrial sector can collect on-site only for 18 percent of its energy needs. If the industrial area is expand by 2800 acres of additional land, the sector can meet all its moderate temperature energy (250^{o}F to 600^{o}F) needs.
- If the land area of the city is increased 34.5 percent (from 10,000 acres to 13,450 acres), all three sectors of the hypotheti city can be energy self-sufficient. The resulting energy self-sufficient city of 13,450 acres is still less than the median are (14,780 acres) of 23 existing U.S. cities of about the same popul tion.

Summary

It is concluded that these results can be achieved without major shi urban form, density, or municipal operations. For example, passive solar residences need not look different from conventional houses, and passive space commercial/institutional buildings may be virtually indistinguishab from existing versions that consume up to twenty-five times more energy. most obvious difference in the physical appearance of the commercial sect in Future 3 will be covered parking areas supporting solar collectors. T industrial sector of the Future 3 city will be the most different in appe compared to today's city.

On balance, environmental quality is not expected to be compromised. trends are perceived as one proceeds from Future 1 to Future 3. The firs

of the overall study is that transitional problems are specifically excluded.

CITY IN 2025

Source of Energy Supply (Btu's x 10^{12})	Future 1	Future 2	Future
Total Residential Supply	4.948	4.948	4.078*
Total "Imported" Supply	4.725(95.5%)	3.383(66.4%)	0
Total Collected On-Site	0.217(4.5%)	1.565(31.6%)	4.078(
Housing Stock Distribution			
Uninsulated Versions	29.0%	37.9%	0%
Standard Versions	68.8%	67.7%	0%
Passive Design Versions	2.2%	12.6%	100%
Total	100.0%	100.0%	100%
On-Site Collector Areas (square feet)			
Flat Plate Solar Thermal (@250,000 Btu's/Sq. ft./Year)	572,000	4,564,000	1,852,0
Photovoltaic Collectors (@34,100 Btu's/Sq. ft./Year)	733,000	3,519,000	34,280,0
Total Collector Area	1,305,000	8,083,000	36,132,0
Total garage, porch and building roof area for collectors**	39,308,000	39,967,000	44,800,0
Percent Coverage	3.3%	20.2%	80.7%

IN COMMERCIAL SECTOR OF HYPOTHETICAL

CITY IN 2025

urce of Energy Supply (Btu's x 10^{12})	Future 1	Future 2	Future 3
tal Commercial Supply[1]	3.540	3.540	3.540
tal "Imported" Supply	3.384(95.6%)	2.949(83.3%)	0.97(27.
tal Collected On-Site	0.156(4.4%)	0.591(16.7%)	2.114(59
of-mounted Collectors[2] (Acres)			
at plate hot water	17	81	35
otovoltaic	19	68	396
ototal	36	149	431
of roofs)	(8.4%)	(34.6%)	(100%)
llectors mounted above rking lots[3]			
otovoltaic	0	0	249*
lar Thermal Electric	0	3	0
ototal	0	3	249
of parking)	(0%)	(0.6%)	(50%)
tal[4]	36	152	680
of available area)	(3.9%)	(16.4%)	(73.3%)

IN INDUSTRIAL SECTOR OF HYPOTHETICAL CITY IN

2025

urce of Energy Supply (Btu's x 10^{12})	Future 1	Future 2	Future 3
tal Industrial Supply	19.90	19.90	19.90
tal "Imported Supply	18.87(96.6%)	17.05(85.7%)	16.28(81
tal Collected on Site	0.67(3.4%)	2.85(14.3%)	3.62(18
-Site Collected Energy urces (Acres)			
tal Energy (Solar hermal and Solar hermal Electric)	47	63	200
rabolic Trough & Solar hermal Collectors	27	180	200
at Plate Hot Water ollectors	---	216	200
otovoltaic Collectors	---	43	---
ototal On-Site ollection	74	502	600
of Industrial Land Area overed by Solar echnologies	12.3%	83.7%	100%

f additional 2800 acres of on-site collectors are added to the 600 acres in e Industrial sector, all energy demands except for high temperature (greater